Concurrent Design at JPL
-Status and Plans-

Presented
by
Dr. Knut I. Oxnevad

at the
New Design Paradigms 2002 Workshop

Double Tree Hotel
Pasadena
June 25-27, 2002

Pasadena, CA, June 25, 2002

1. Contributing Organizations
2. Basics
3. Challenge
4.Meeting the Challenge
5. The NPDT
   a, Status
   b, Latest Developments (CFD, VT, Immersive 3D)
7. Beyond Engineering
8. A Systems Design Curriculum
9. Future Visions

The work described in this presentation was carried out in part at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

The NPDT

Contributing Organizations

Jet Propulsion Laboratory (JPL)/California Institute of Technology

- Mission Development
- Modeling and Simulation
- Payload Division
- Ground Operations
- Power
- Science
- Thermal
- Telecom
- Mars Rover Technology

Mars Program Office

NASA

- Code FT HQ
- Marshall
- Langley

NASDA

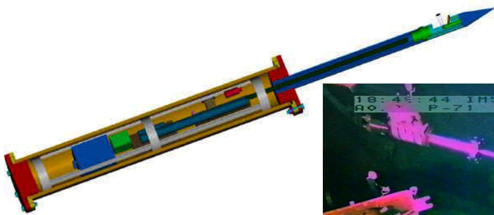
- Tsukuba Space Center

Stanford University, CA

Old Dominion University, VA

The NPDT

Track Record...



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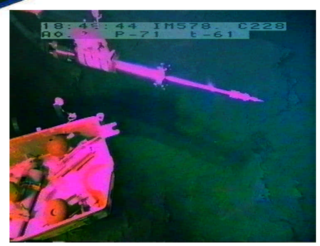
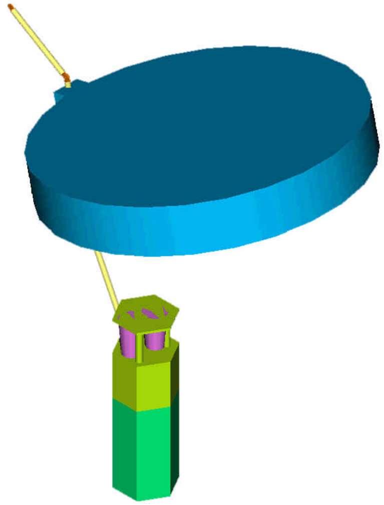
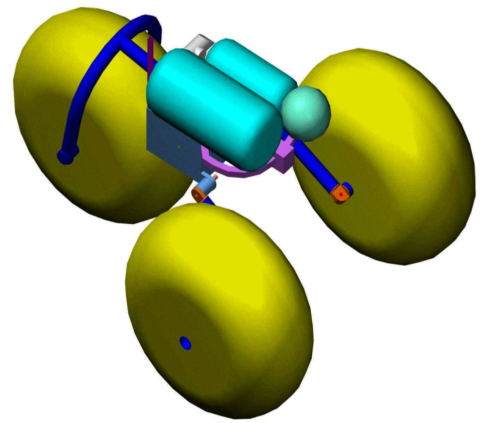


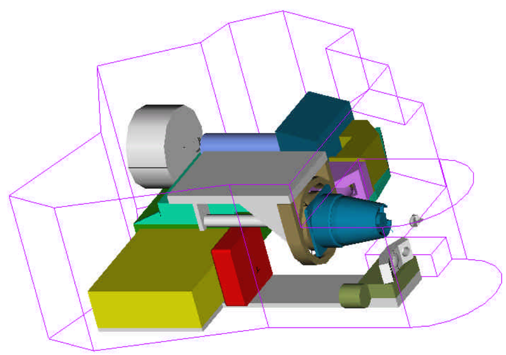


IIP / OSIRIS



Mars Outpost
Rover

Concurrent Design Teams Supported ~ 60 Studies Over the Last 3 Years

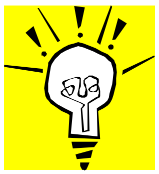


DS (ST)-4 / CIRCLE

Design Maturity Improvements: <10
Time Compression: <4

The NPDT

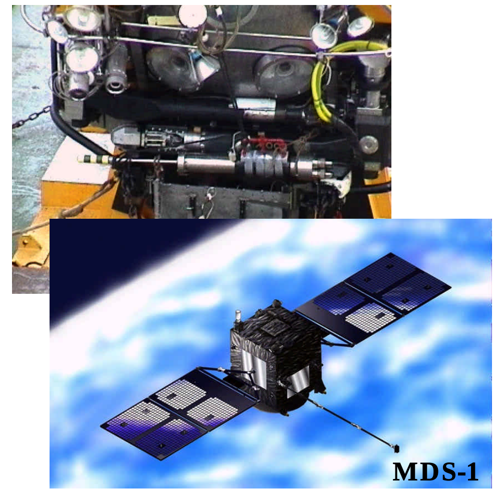
Goal!



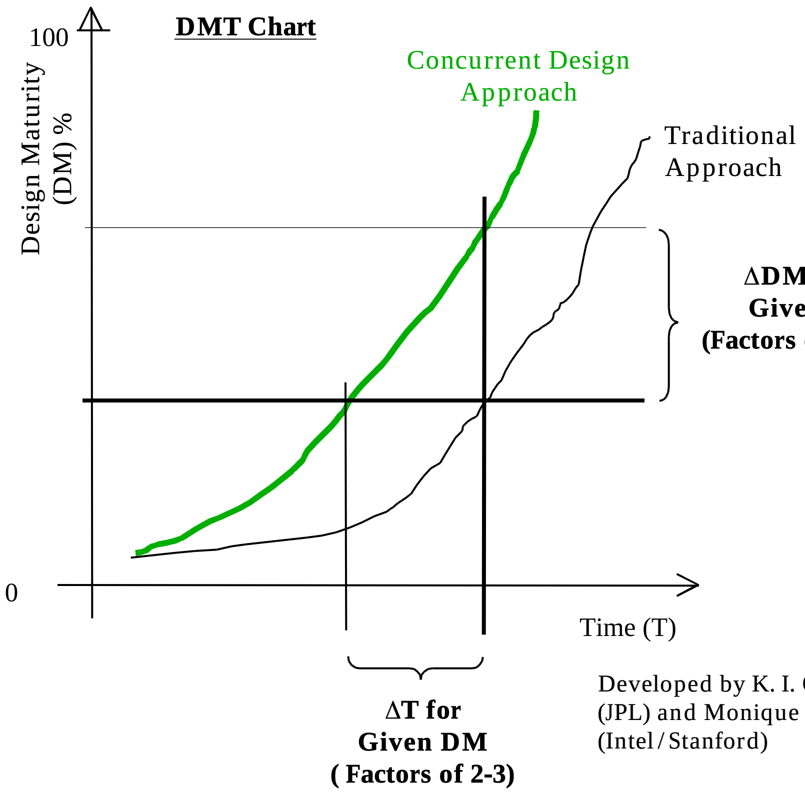
Concept

Compressed Design Cycle & Improved Quality

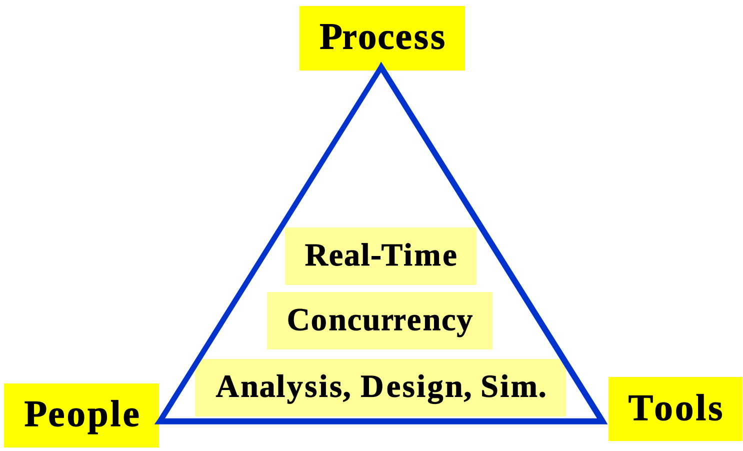
Space System (HW/SW)



It's About...



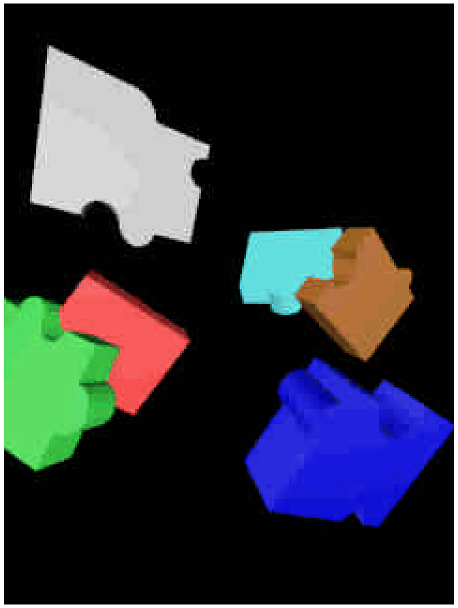
Developed by K. I. Oxnevad (JPL) and Monique Lambert (Intel/Stanford)



PPT-Model

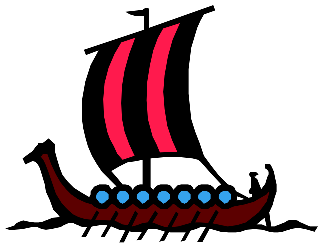
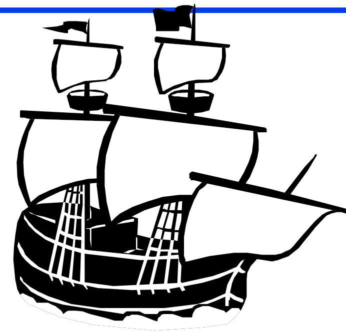
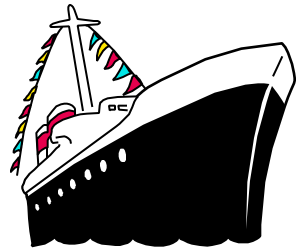
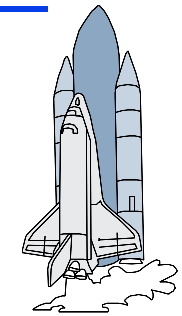
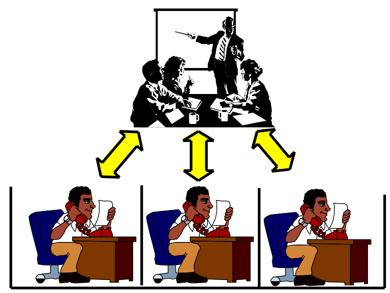
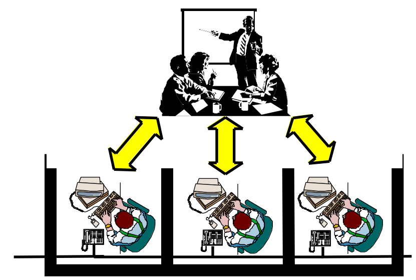
The Challenge

The biggest Challenge facing Space Development today does not lie within a specific ***technology/discipline****, but rather in our ability to make these* ***technologies/disciplines*** *work efficiently together to achieve our* ***objectives****.*

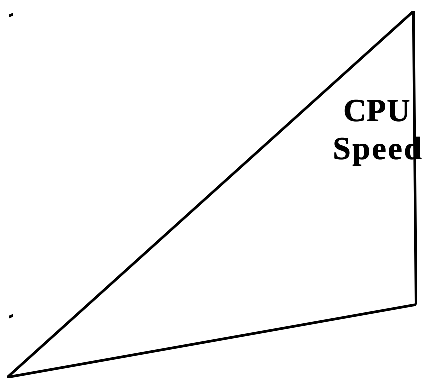


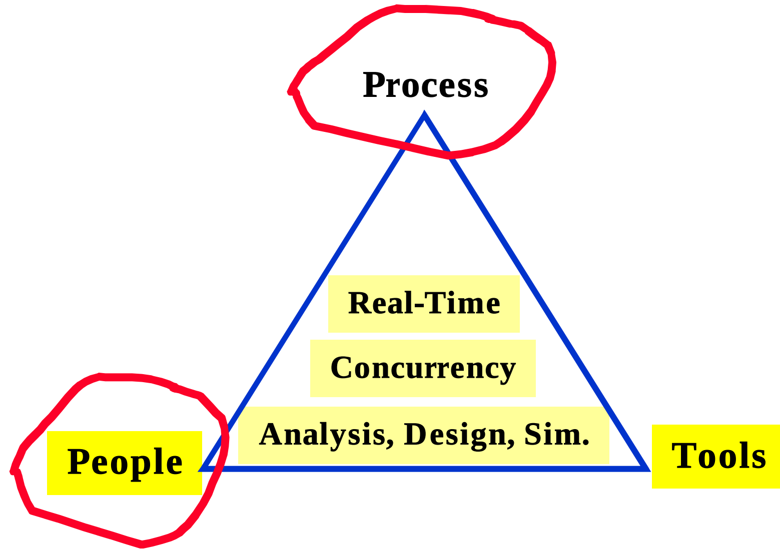
We must find entirely new ways to achieve our objectives ------ Sean O'Keefe

A Historical Perspective

				
	1000	1500	1950	1995
Design Complexity	**Low**	**Medium**	**High**	**Very High**
Basis for Design Decisions	**Experience**	**Experience (H) Computations (L)**	**Experience (L) Computations (H)**	**Experience (VL) Computations (VH)**
Design Collaboration				
Design and Analysis Approach	**•Real Time •Working Design Session- •Hands-On/"Touch and Feel" •Designer and Builder the same**	**•Real Time •Working Design Sessions •Hands-On/"Touch and Feel" •Designer and Builder Co-Located**	**•Off-Line •Office Work •Meetings •Design Reduced to Drawings and No. •Designers and Builders Separated**	**•Off-Line •Office Work •Meetings •Design Reduced to Drawings and No. •Designers and Builders Separated**

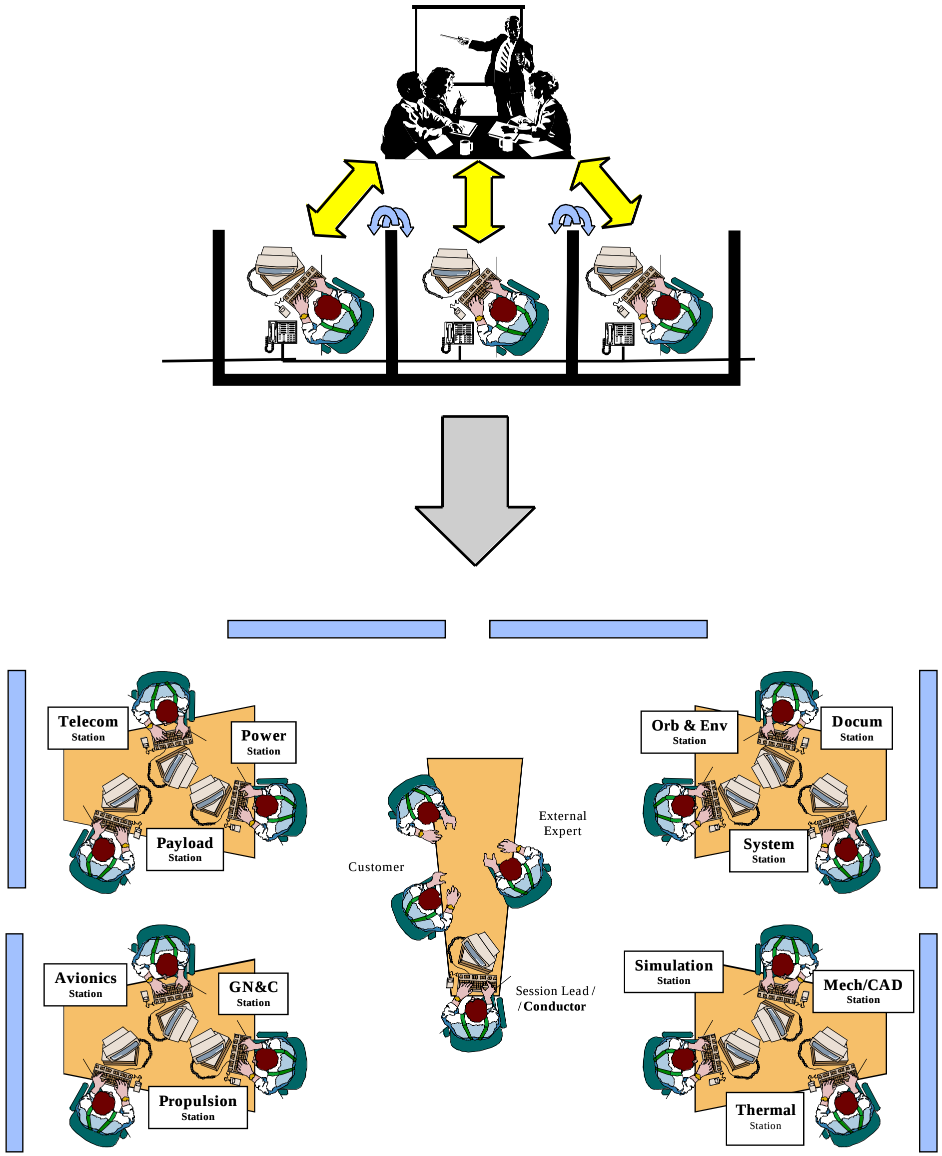
The NPDT


CPU
Speed

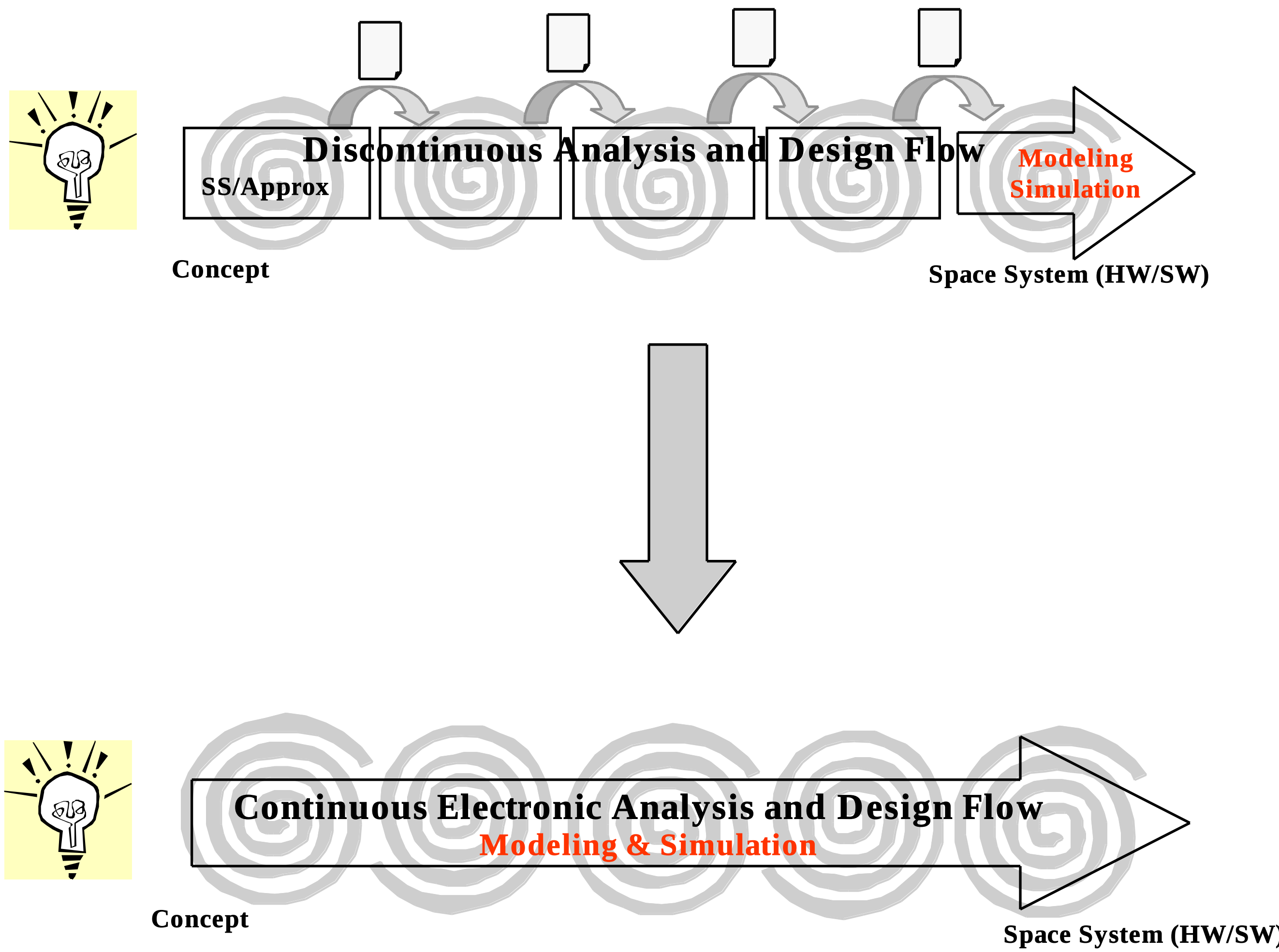

Process
Real-Time
Concurrency
Analysis, Design, Sim.
People
Tools

Back to Working Design Sessions

Concurrent Design



Design Flow Improvements



The Steps...

Related

International IT Award | **ISU SSP**

"8 Principles of CD" (EUSEC2000) | **MSFC CDE** (NASA HQ) | **NASDA** | **UoM**

New Paradigms Workshop (NASA HQ) | **Stanford**

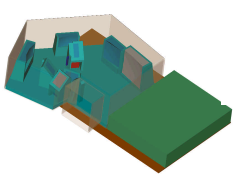
Team I -> NPDT | **Team I** -> Div 38 | **MSMS Team** Set Up

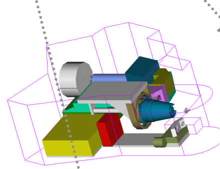
SURF (LATIS) | **SURF** (MEGAROVER) | **John Deere**

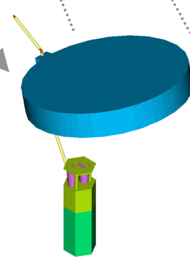
R &D

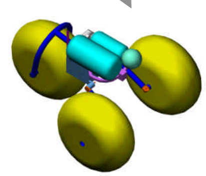
1997	1998 (5)	1999 (12)	2000 (28)	2001 (2 +)	2002 (?)
Optical Mech Thermal Syst Cost	Structural	Simulation End-End Syst Imp/Exp Ext Files Super Computer	Radiation Calculations	Power Sim Telecom Avionics Ground Systems	

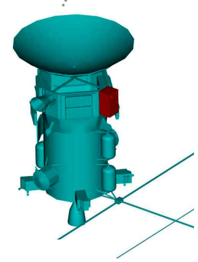
Customer Support

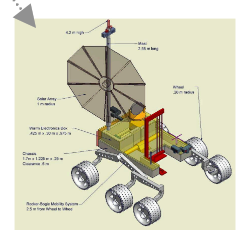








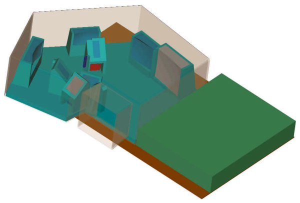




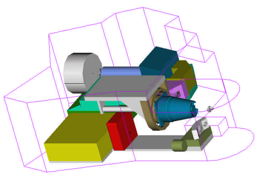
~ 60 Customers Supported

In A Nut Shell

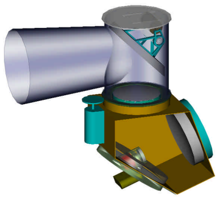
Discovery Phase 1 Gulliver



DS (ST)-4/CIRCLE

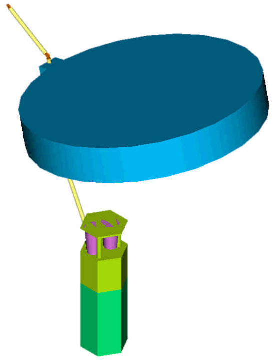


Search Camera for the CNES Orbiter

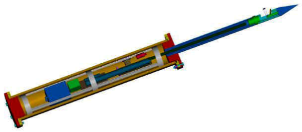


- *Concurrent **Design** and **Analysis** Environment*
- ***Real-Time** Analysis and Design*
- *Total **Systems** Approach, Multi-Disciplinary Team*
- *Standing Design Team*
- ***Customer** Actively Participates in the Design Sessions*
- *Input Parameters are Challenged in Real-Time*
- *Involved External Experts in the Design Sessions*
- *Joint Sessions with other NASA Centers*
- *From Concept to Engineering Drawings*
- ***Interconnected, High-End** Optical, Microwave, Mechanical/CAD , Thermal, Structural, Dynamics, Simulation, Orbital, Electronics Analysis and Design Tools, such as Code V, ZeMax, <u>Mechanical Desktop, (Inventor), NASTRAN, Thermal Desktop, Adams,MODTool, and visualNASTRAN</u> + (PowerTool, Telecomm,. Avionics)*
- *Applications Utilize a **Common** CAD Developed **Geometry***
- *Open Environment, import/export of STEP, NASTRAN files, etc., from/to JPL, other NASA centers, and Industry*
- *Technology Insertion Through Cooperation with MDL/TAP*
- *Analysis and Design Time Cut from Months to Weeks*

IIP/OSIRIS

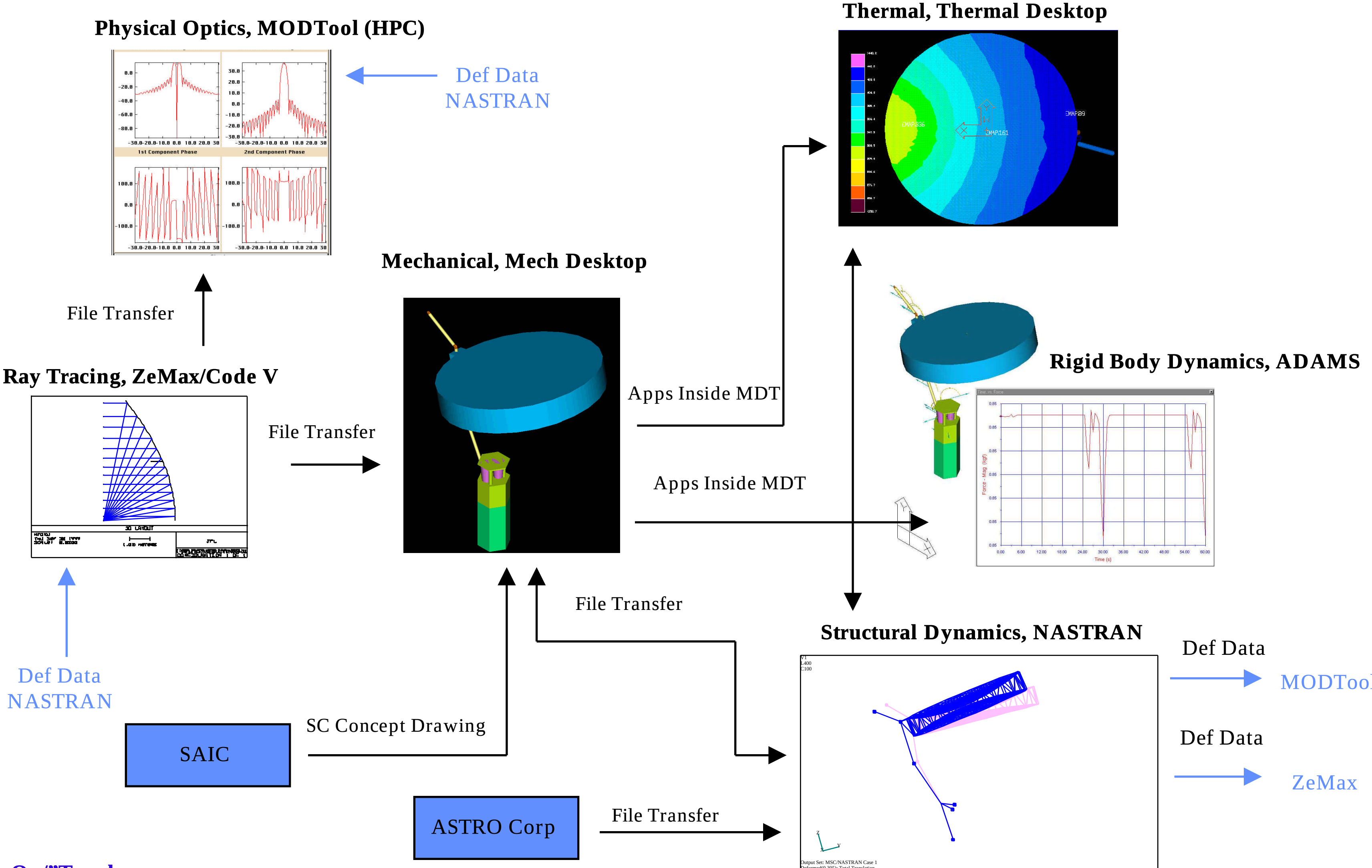


Loihi Deep Ocean, Volcanic Vent Probe



The NPDT

Approach (Design Paradigm):
Integrated, High-End Analysis and Design

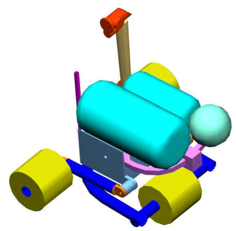


• **Hands-On/"Touch and Feel"**

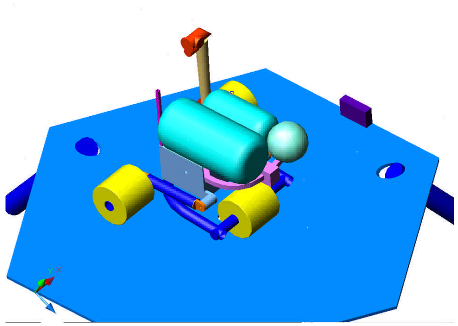
The NPDT

Approach
Sizing, Configuration, and Simulation

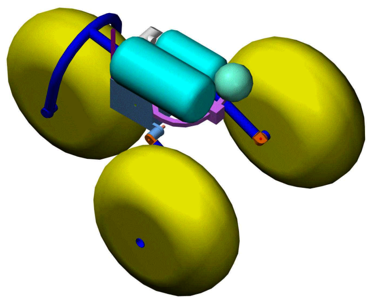
Mars Outpost
50km Fuel Cell Rover



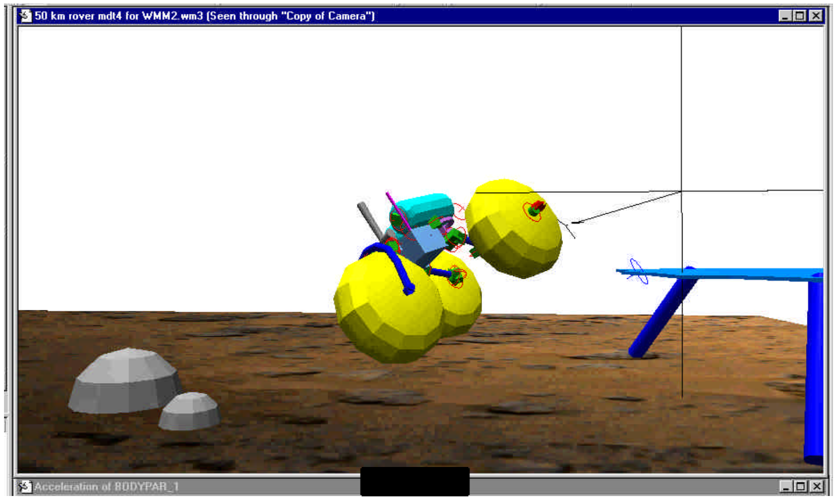
Lander Configuration



Deployment Sequence

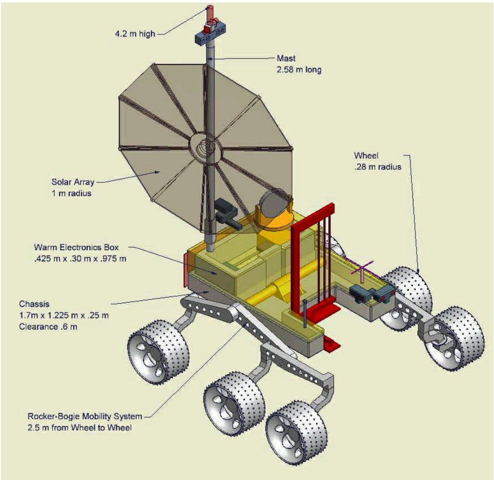


Surface Configuration



Operational Scenario Simulation

SURF 2001 Rover
(MSMS Rover Team)

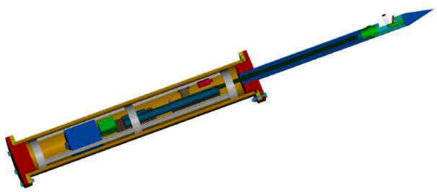


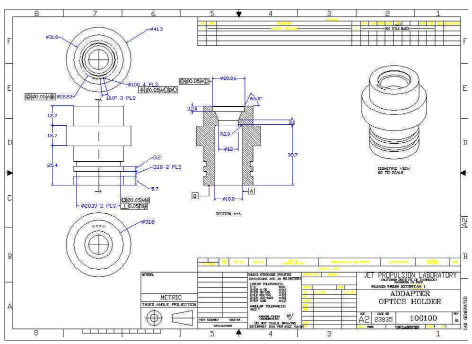
Support: Mechanical (parts and assemblies), Structural, Surface Mobility/Ops Simulations, Trade Studies, Mass Summary

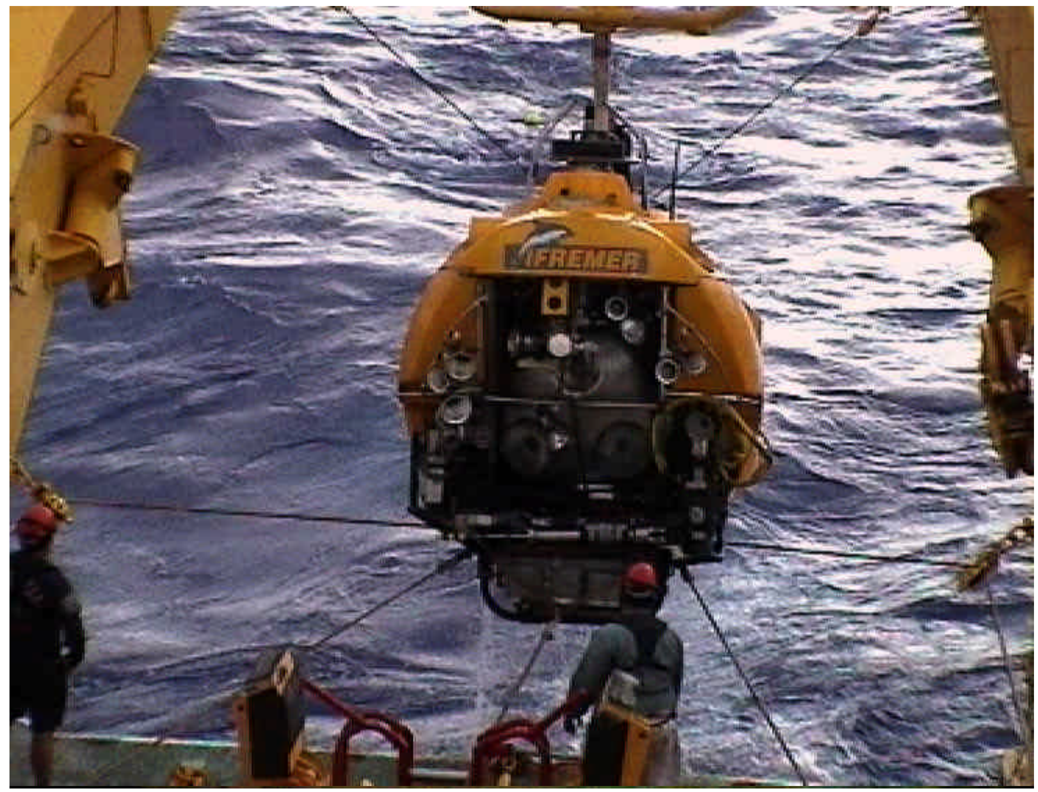
The NPDT

Approach

Concept, Hardware, Science Data

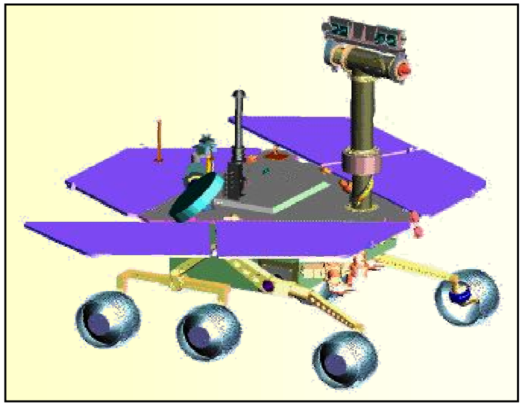




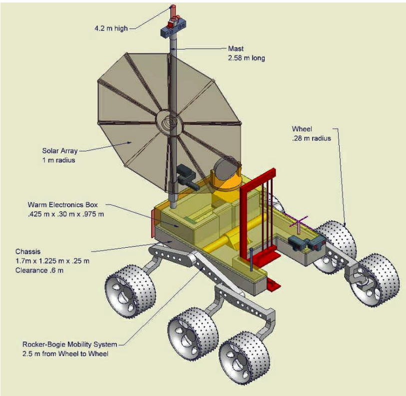


Support: Mechanical (parts and assemblies), Structural, Electronics, Optics, and Engineering Drawings

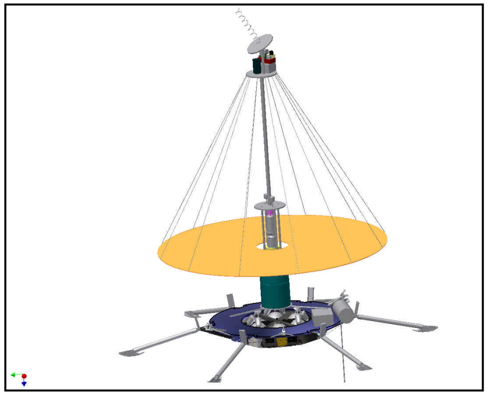
Mars Surface Mobility Studies
Mars Advanced Studies



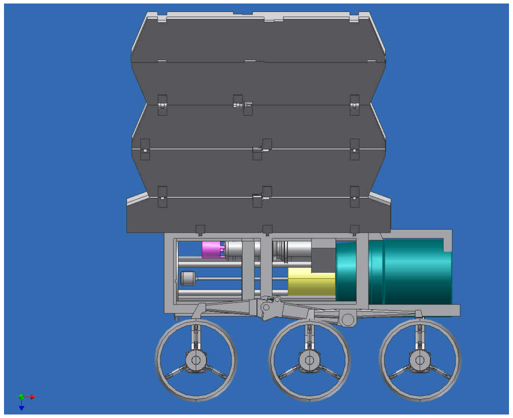
Volcanology, MER Derivative



Polar Layer Deposit (PLD)



Fission Powered Polar Based Cryobot Lander Mission

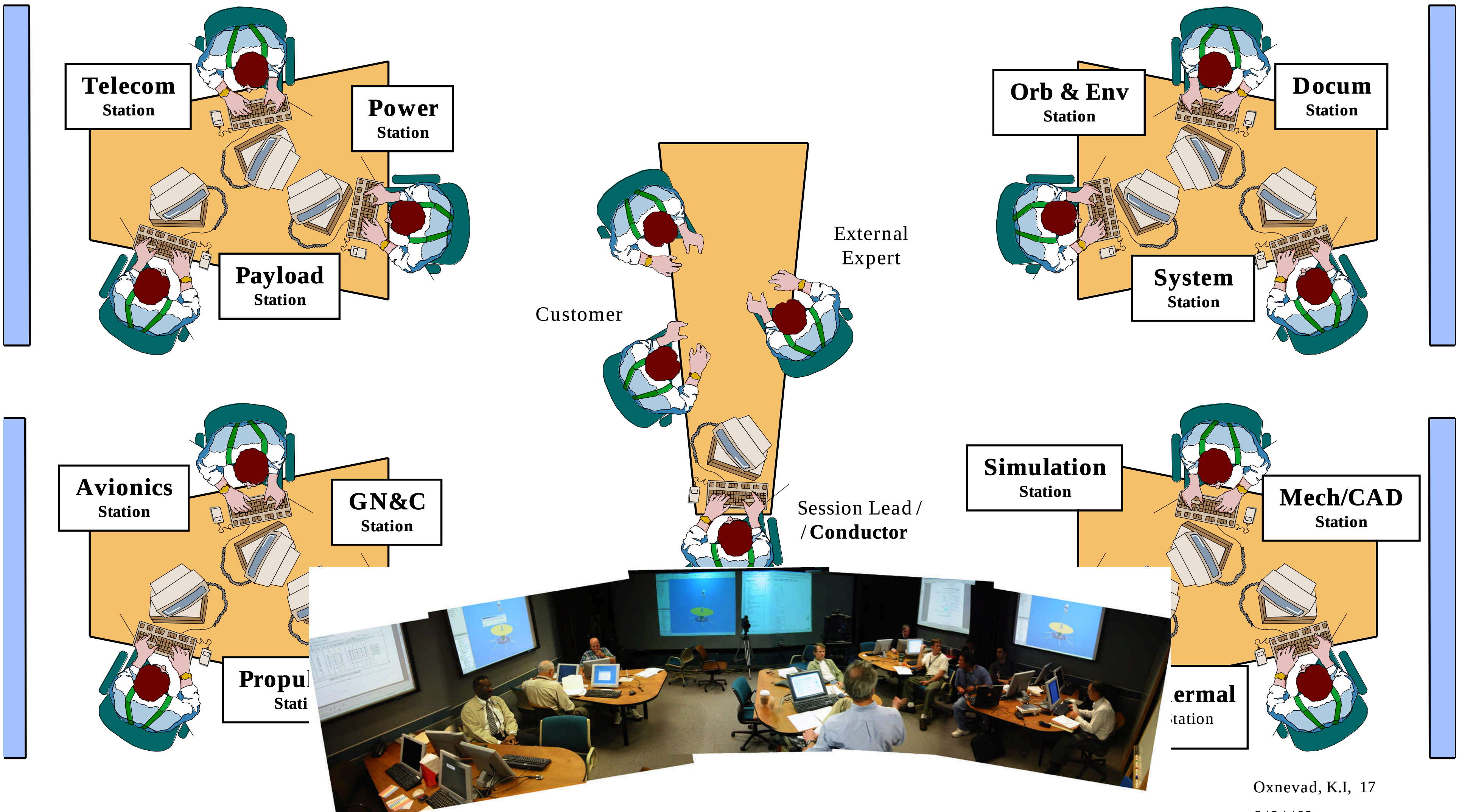


Fission Powered Rover Mission

Images Courtesy Hovik Nazaryan and Guillermo Olarte

The NPDT

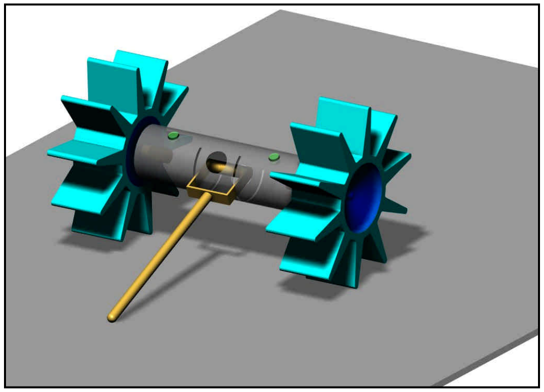
The Mars Surface Mobility Study (MSMS) Team

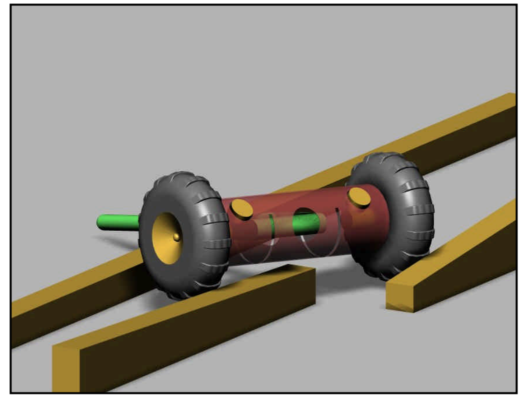


Photo, Courtesy Ben Shaw

The NPDT

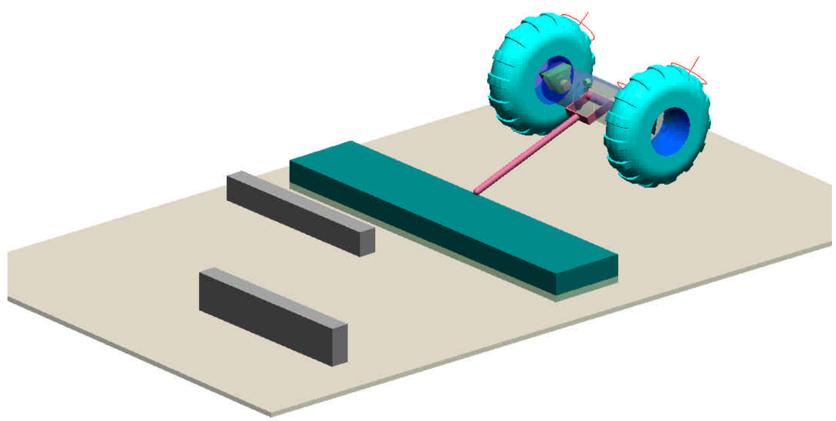
Simulation/Virtual Testing





<u>Trades</u>

Wheel Diameter
Castor length
Wheel Base
Wheel plus rim
Castor Mass
Axelrod Mass
Axel Mass

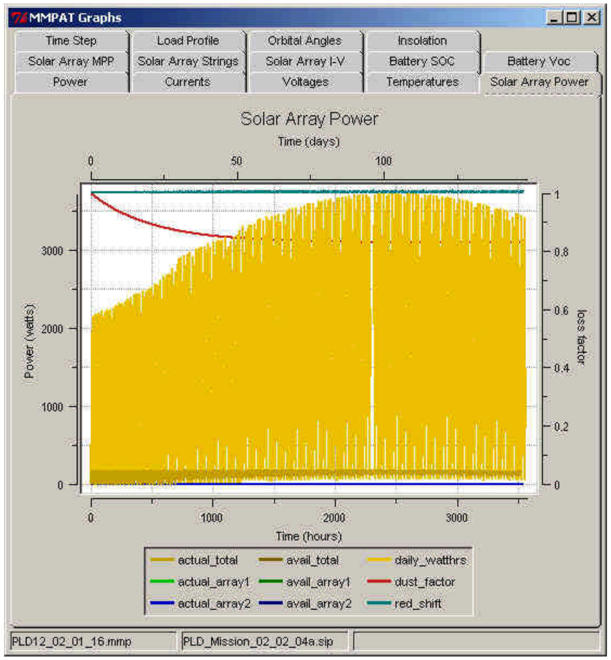


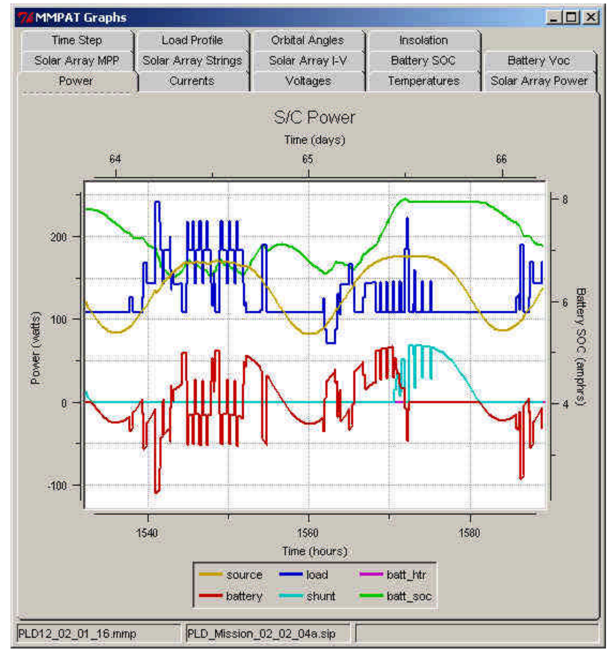
<u>Tools Used</u>
Inventor
and visualNASTRAN

Images Courtesy Hovik Nazaryan and Guillermo Olarte

The NPDT

Power Analysis/Simulation Tool
Mars Mission Analysis Tool (MMAPT)





JPL's Mars Mission Analysis Tool (MMAPT) Included in Environment

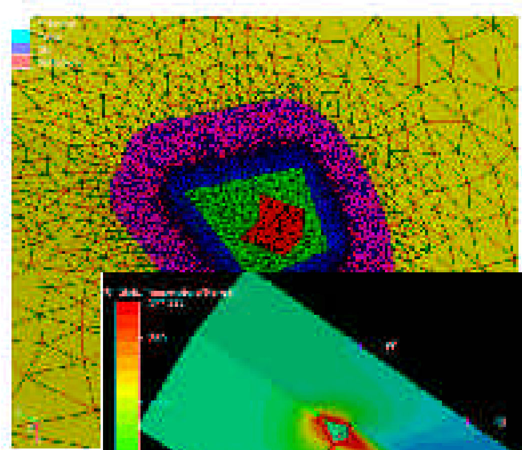
Calculates, for a Given Location, Date, and Mission Power Profile:

- Solar Power Available
- Battery Charge and Voltage
- Solar Panels and Battery Sizes/Capacities

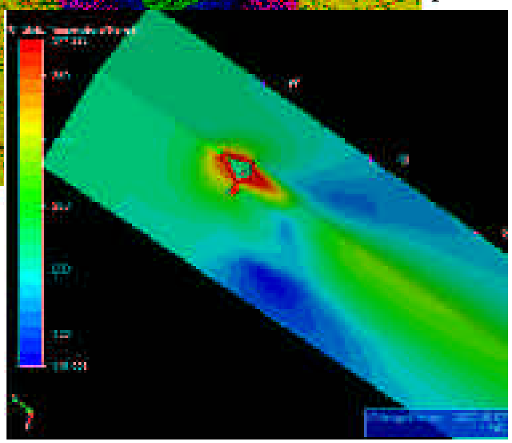
Plan to Introduce Avionics and Telecom Tools Later

Images Courtesy Erik Wood

CFD and Immersive 3D COTS Tools



Closeup Meshed probe - CFdesign



Sample temperature distribution - CFdesign

Dr Tibor Balint, Assessment of Commercial Off the Shelf Computational Fluid Dynamics (COTS-CFD) Tools to Enhance the Concurrent Design Environment at NASA-JPL, JPL, May 2002

Objective

Evaluate CFD and 3D Immersive Tools For use in a Real-Time Concurrent Design Environment

<u>Evaluation and Recommendation Completed</u>

Courtesy, Dr. Tibor Balint, 2002

Beyond Engineering

The NPDT

Background Image, Courtesy, S. Shariq

Roman Structures

Build "real prototypes" (with considerable trepidation)

Observe their behavior

Learn from experience

Vasco Da Gama Bridge over Tagus

Create, test and refine multiple "virtual prototypes" of real structure in its context

Predict performance, optimize trade-offs

Build real structure with confidence

Nano Engineering

Enterprise Design & Operations

Project Plan & Operations

Surgical Teams

VC Support

Bio Engineering

NASA Projects/Enterprises

Science

Regional Planning

Vision: **Empower** 21st Century Managers to **Design and Operate Organizations the way Engineers** and **Scientists Work**

Computer Sciences
Social Sciences
Cognitive Sciences
(Stanford)

Economics
Finance
Marketing
(EDL)

Concurrent Design Basics
Real-time, **concurrent**, teams, sophisticated true physics **modeling and simulation** to create designs in **shorter time** and with **higher quality** that can be successfully developed and operated

Systems Engineering

Oxnevad, Dissertation

Concurrent Engineering

The NPDT

Curriculum/Support
B. Discipline., Performance, and Design Team Training

1. Concurrent Design Exercise

Train people from Cross-Centers to work together as a team, utilize the concurrent design approach (real time, concurrency), utilize higher-end tools to develop a specific technology/project/mission.

- Relevant topics to be selected by Programs, Centers, or Enterprises.
- Such training possible at the CSMAD at JPL: 5-7 days
- Process and Tools Training
- **Learn to Live in** a Concurrent Design Environment
- Member and Leader Training
- History: SURF, University of Michigan (Mars Program)

MSR Study, University of Michigan, April 1-5, 2002
Week Training and Problem Solving

Curriculum/Support

B. Discipline., Performance, and Design Team Training

CSMAD*

3. Design and Analysis Support for Difficult Projects

Solve specific problems that are hard to solve in a short time any other way.

•Relevant Experts on Team (NASA, none NASA, JPL)
•On-site and through Internet
•DoE Mars Surface Fission Power Study
•Experts could be picked from experts already trained

Images Courtesy Ben Shaw

* CSMAD: Center for Space Mission Analysis and Design

The NPDT

Future Directions

- Develop An Art to Part Design Process for space vehicles (Concept to Hardware)
- Better Utilization of COTS tools in the Analysis, Design, and Simulation Areas
- Better Utilization of STEP
- Use of HPC (supercomputers, parallel computing systems)
    - CFD, Thermal, Structural)
- Utilization of Concurrent Design Teams **throughout** the **Design Process**, and throughout the **Organization**
- Define, train, and **set up of new Design Teams** (JPL, NASA centers [MSFC, LaRC, NARC,], NASDA, **industry**, and academia [Stanford and MIT])
- Set up **Workshops** to Bring Focus on New Design Paradigms (http://nsd2001.jpl.nasa.gov)
- Develop Working **Relationships with Academic Organizations**/Initiate Research
    - Caltech (SURF, on-going)
    - International Space University (ISU)
    - MIT, Stanford, University of Irvine California, Pasadena Art Center, University of Southern California (TBD)
    - University of Michigan (April 2002)
- Transfer the Concurrent Design Process to New Domains (Stanford, in Progress)

The NPDT

Creates Winners!